Broadband Microwave Spectrometer for Liquid Media

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Molecular biology, one of the new fields of science, emerged in the mid-20th century. Molecular biologists have unveiled the nature of proteins and nucleic acids (ribonucleic and deoxyribonucleic acids or RNA and DNA), which are macromolecules essential to life processes. Their research led directly to the emergence of new, innovative techniques to study and understand life processes. One such technique is the Broadband Microwave Spectrometer developed at Los Alamos, which can be used to measure the rate at which a water-based solution or another liquid sample will absorb microwaves of different frequencies. The unique features of this invention were recognized by an R&D 100 Award, one of seven won by Los Alamos scientists in 1990.

The Need for a New Spectrometer

Scientists know that a thorough understanding of the motions of biological molecules can give them insight into the structure of molecules and therefore a better understanding of the basic functions of these molecules in life processes. Molecules significant to all living organisms—such as DNA and proteins—have characteristic motions, which take place at different frequencies; some are fast, occurring at very high frequencies (comparable to those of infrared light), while others are slow, occurring at low frequencies, in the microwave range. It is the slow motions that are difficult to measure and analyze because biological molecules are naturally found in aqueous solutions, and water shields the molecules from microwave radiation. Traditional, successful microwave spectrometers (normally used for measuring gas samples) are not easily adaptable to liquid media, and they operate over an inherently limited range of frequencies. Moreover, traditional methods now in use for liquid media are capable of only indirect measurements of the rate of microwave absorption.

Unlike them, the Broadband Microwave Spectrometer provides a *fast*, *direct*, and *less expensive* means of measuring the spectra of microwaves absorbed by molecules found in liquid media. This instrument allows scientists to look at liquid samples and literally pluck at molecules to see at what frequencies they vibrate, much in the manner that a guitarist plucks at the strings of his instrument. The only special requirements of this technique are that the sample be a moderate transmitter of red light (the sample should not block laser light and therefore must be at least partially transparent) and that the system be located in a relatively vibration-free environment.

The Invention—Description and Advantages

A few components of the Broadband Microwave Spectrometer are fundamental to the system. They are a low-power, high-stability laser, a laser interferometer (an instrument in which light from a source is split into two or more beams), and a small, open microwave transmission line (microwave power is injected into the sample through the transmission line) that ensures the instrument's capacity to operate over a broad range of frequencies. The sample is placed in an optical cell in the laser interferometer. For each frequency, millisecond pulses of microwave power heat the sample within moments. At the same time, they cause a fluctuation in the optical signal emerging from the interferometer. Unlike standard techniques, the new spectrometer measures directly the rate at which microwaves are absorbed for each value of frequency in the intended range.

Although not fundamental to the spectrometer's operation, a number of other components, such as the phase-locked detector system and the vibration-isolation table, are essential enhancements needed to provide the required sensitivity and general performance of the technology. The phase-locked detector is a sophisticated electronic filter that is capable of finding a little signal in a lot of noise; it thus provides improved signal-to-noise ratios for the measurement. The vibration-isolation table ensures a vibration-free environment for the interferometer.

In contrast to conventional spectrometers, the Broadband Microwave Spectrometer allows a direct, fast (up to one hundred times faster than conventional methods), and reliable measurement of the rate of microwave absorption. The use of a transmission line makes the instrument versatile and allows measurements over a broad spectral range.

* *This research was in part performed while Pritish Mukherjee was a postdoctoral fellow at Los Alamos.*

For more information about the Broadband Microwave Spectrometer, please contact Dr. Ronald E. Barks, Industrial Applications Office, Los Alamos National Laboratory, P.O. Box 1663, Mail Stop M899, Los Alamos, NM 87545, Telephone (505) 667-3839.

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Applications

The Broadband Microwave Spectrometer can be used to measure the spectrum of microwaves absorbed by any molecular species in aqueous solution, to identify the presence of various constituents in liquid solutions, and to measure the spectrum of microwaves absorbed by any transparent liquid. It is therefore an important tool for molecular biologists who prefer to make measurements on liquid (particularly aqueous) samples, rather than on crystals or powders; the last two groups of samples do not represent the natural state for biological molecules and are best suited for traditional spectroscopic techniques.

A number of interested companies have already inquired about our new spectrometer, and the Industrial Applications Office at the Laboratory has sent out descriptions of the technology.

PHYSICISTS Irving J. Bigio, Timothy R. Gosnell, and Pritish Mukherjee have formed a creative and well-matched team in developing the new spectrometer that brought them a 1990 R&D 100 Award.

Irving Bigio received his B.S. in physics in 1969, his M.S. in physics in 1970, and his Ph.D. in physics in 1974 from the University of Michigan. Since 1974, Bigio has been a staff member and deputy group leader, and he is currently group leader in the Chemical and Laser Sciences Division at Los Alamos. In 1976, after receiving a Fulbright Award, Bigio spent nearly one year at the Weizmann Institute in Rehovot, Israel, as a Fulbright scholar. At the invitation of the Danish National Research Council, Bigio spent a few summers as a visiting professor at the University of Copenhagen, Denmark. His current areas of interest include general laser physics and modern optics, medical applications of lasers and optics, nonlinear molecular dynamics and biopolymers, and laser interactions/spectroscopy in biopolymers.

After earning a B.A. in physics from the University of California at San Diego in 1979, Timothy Gosnell went to Cornell University, where he obtained his M.S. in physics in 1983 and then his Ph.D. in physics in 1986. Gosnell joined the Laboratory as a staff member in the Chemical and Laser Sciences Division in 1986. Among his research interests are ultrafast spectroscopy, ultrafast laser technology, and, more recently, defects in solids, an area of materials science.

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Irving J. Bigio (left) and Timothy R. Gosnell

Pritish Mukherjee received his B.S and M.S. in physics from the University of Delhi, India, in 1976 and 1978. He then obtained a second M.S. in physics in 1984 and a Ph.D. in electrical engineering in 1986 from the State University of New York at Buffalo. He came to the Laboratory in 1986 as a postdoctoral fellow. Mukherjee contributed his experience in biophysics, laser spectroscopy, and experimental physics to the development of the spectrometer. Currently, he is assistant professor with the Department of Physics at the University of South Florida.

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